COMPARISON OF MORPHOLOGIC CHANGES OF ROTATOR CUFF MUSCLES FOLLOWING FAST ISOKINETIC TRAINING AND TRADITIONAL ISOTONIC TRAINING IN JUNIOR STATE-LEVEL WEIGHTLIFTERS

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LIST OF SYMBOLS, ABBREVIATIONS AND ACRONYMNS

CSA	Cross sectional area
PA	Pennation angle
FIT	Fast isokinetic training
TOT	Traditional isotonic training
SS	Supraspinatous muscle
SC	Subscapularis muscle
ISTM	Infraspinatous muscle and teres minor muscle
MRI	Magnetic resonance imaging
CT	Computed tomography
PACS	Picture archiving and communication system

ABSTRAK

Objektif: Untuk menilai saiz otot rotator cuff dan sudut serat otot otot supraspinatous dalam dua jenis senaman iaitu latihan isokinetik pantas dan latihan tradisional isotonik dalam sukan angkat berat peringkat negeri.

Kaedah: Subjek (n = 16) telah diambil melalui Majlis Sukan Negeri Kelantan. Mereka dipadankan berdasarkan jantina dan berat secara rawak ke dalam kumpulan tradisional isotonik latihan (TOT) dan kumpulan latihan isokinetic pantas (FIT). Kedua-dua kumpulan telah melalui 24 sesi program latihan tiga kali seminggu selama 8 minggu. MRI dilakukan sebelum mula latihan dan selepas latihan. MRI otot rotator cuff telah dijalankan dan pengukuran CSA dan PA telah dilakukan. **Keputusan:** CSA daripada empat otot rotator cuff meningkat selepas program latihan dengan peningkatan yang ketara ($p < 0.05$) didapati dalam CSA otot supraspinatous (SS) dan otot infraspinatous bersama teres minor (ISTM), tetapi tidak dalam otot subscapularis (SC). Kenaikan ketara dalam CSA ditemui dalam semua otot rotator cuff dalan subjek yang menjalani FIT tetapi bagi subjek yang menjalani TOT, kenaikan ketara dalam CSA hanya dijumpai di SS, tetapi bukan dari SC dan ISTM. Pennation angle (PA) otot supraspinatous meningkat dengan ketara selepas program intervensi. Kenaikan ketara dalam PA ditemui dalam semua otot rotator cuff dalam subjek yang telah siap menjalani FIT atau TOT. **Kesimpulan:** Program FIT menunjukkan peningkatan ketara CSA dan PA dalam otot rotator cuff.

Kata kunci: Latihan isokinetik, *otot rotator cuff, cross sectional area, pennation angle*

ABSTRACT

Objective: To evaluate the size of rotator cuff muscles and muscle fiber angle of supraspinatous muscle in two different types of exercise which are fast isokinetic training and traditional isotonic training in state-level weightlifters.

Methodology: Subjects (n=16) were recruited through Majlis Sukan Negeri Kelantan. They were gender- and weight- matched and randomly assigned into traditional isotonic training group (TOT) and fast isokinetic training (FIT) group. Both groups went through 24 sessions of training programme three times per week for 8 weeks. MRI was done before the commencement of the training and after the training. MRI of rotator cuff muscles were performed and measurement of CSA and PA were done. **Results:** CSAs of the four rotator-cuff muscles increased after the intervention programme with significant improvements ($p<0.05$) found in CSA of supraspinatous muscle (SS) and infraspinatous with teres minor muscles (ISTM), but not in subscapularis muscle (SC). Significant increment in CSAs were found in all rotator-cuff muscles of subjects who underwent FIT but for subjects who underwent TOT, significant increment in CSA was only found in SS, but not that of SC and ISTM. Pennation angle (PA) of the SS significantly increased after the intervention programme. Significant increment in PA was found in all rotator-cuff muscles of subjects who underwent either FIT or TOT. **Conclusions:** Fast isokinetic training show significant increment of CSAs and PA of the rotator cuff muscles.

Keywords: *Isokinetic training, rotator cuff muscle, cross sectional area, pennation angle*

CHAPTER 1 : INTRODUCTION

1.1 INTRODUCTION & LITERATURE REVIEW

Weightlifting is highly associated with weight-related injuries of the shoulder joint. Many of the muscular injuries were observed among the athletes due to inadequate muscle strength. Fast isokinetic training (FIT) is a type of exercise that allows maximum muscle contraction throughout the full range of joint movement (Izzuna *et al.*, 2009). Isokinetic exercise machine provide constant limb movement against resistance while the speed of limb motion and subsequent revolution per minute remain the same. Therefore, straining of the muscles is highly unlikely since the resistance and speed of the exercise are controlled. This will reduce the likelihood of muscle injury. Improvement of muscular strength due to functional and structural adaptations in muscle tissue (Izzuna *et al.*, 2009) observed from this exercise. Whilst in traditional isotonic training (TOT), tension remains unchanged and the muscle's length changes. Isotonic exercise differs from that of isokinetic whereby in the latter, the exercise speed remains constant.

Typical isotonic weight training that emphasizes on large upper extremity muscles such as the deltoid, neglects the necessary training for smaller joint-stabiliser muscles such as the rotator cuff group (Barlow *et al.*, 2002; Gross *et al.*, 1993). Therefore, it is important to have a balanced strength ratio as well as the overall strength of the shoulder complex to avoid an injury. Isokinetic method of training can be used to restore the imbalances of the rotator cuff muscles group. Rotator cuff muscle are important to stabilise the shoulder joint during lifting. Malliou and colleagues (2004), noted that isokinetic is the most effective type of training in changing the ratio of the rotator cuff muscles compared to multi joint dynamic resistance training and dumbbell isotonic training which further reduce the risk of shoulder injury when performing repetitive lifts.

FIT may be performed concentrically (muscles shorten during contraction) or eccentrically (muscles lengthen during contraction). By using this type of exercise, external forces are applied to the limbs and when maintained over a sufficient period, these exercise may promote functional and structural adaptations in muscle tissue (Izzuna *et al.,* 2009).

Muscular strength is higher in the trained muscle as compared to the untrained muscle after undergoing FIT. Study by Nickols *et al*. (2007) found that muscular strength of the trained leg was significantly higher than the untrained leg of young adult women after 5 months of FIT. The training sessions were performed 3 times per week.

Major adaptive process induced by FIT is muscle hypertrophy. Increase in muscle mass is one of the determining factors for force production capacities which is important for improvement of muscle strength. A study by Guilhem *et al*. (2010) showed that beyond 6 to 8 weeks of training, the improvement in muscle capacities is observed together with an increase in muscle mass. Progressive activation of genes responsible for cellular growth and development which occurs in cellular hypertrophy take place 6 hours post-exercise. Muscle hypertrophy is associated with increased of pennation angle (PA) of muscle fascicles. The increase in the PA leads to an increase quantity of parallel contractile elements which in turn leads to a larger physiological cross sectional area (CSA) and thus higher force production capacities (Guilhem *et al*., 2010).

A study by Soo *et al.* (2014) showed that muscle hypertrophy is associated with an increase in PA. Greater CSA and steeper fiber PA were observed in bodybuilders compared to age-matched sedentary subjects (Kawakami *et al., 1993*). Using ultrasound measurement, Kawakami *et al. (*1993) reported a significant increased in fiber PA from 16.5 to 21.3 degree in the triceps brachii muscle following 16 weeks of resistance training which was performed 3 times per week.

Significant increments were observed for CSA and volume of the quadriceps muscle and muscle fiber area after 14 weeks of heavy-resistance training. Alterations in quadriceps muscle architecture were demonstrated after the training, as manifested by an increase in vastus lateralis muscle fiber PA (Per Aagaard *et al*., 2001).

Elizabeth *et al*. (1996) studied the concentric and eccentric training effects on quadriceps muscle in 60 women using MRI and showed increased CSA of the muscle in eccentric training as compared to concentric training. The same result was also shown in a study by Farthing *et al.* (2003) whereby eccentric training has produced greater muscle hypertrophy than concentric training of arm muscles. Furthermore, training with combination of concentric and eccentric training produced greater muscle hypertrophy (Elizabeth *et al*., 1996). Eccentric training is an efficient process to improve not only the force production capacities, but also the quality of the muscle which is essential in most physical and sport activities (Guilhem *et al*., 2010). Overall, these study showed that the increase in strength after heavy-resistance training are due to muscle hypertrophy.

Measurement of muscle morphology can be obtained by using MRI, CT scan or ultrasound imaging techniques. MRI is regarded as the premier modality for imaging of human skeletal muscle and for muscle morphometry. Unlike CT, MRI does not require the exposure of ionizing radiation to the patients (Walton *et al.,* 1997).

Previously, muscle fiber PA has been obtained from dissection of cadaveric specimens. However, more adequate measuring methods based on ultrasound have been introduced, which makes it possible to perform *in vivo* measurement of muscle fiber PA (Per Aagaard *et al*., 2001).

Soo *et al.* (2014) measured muscle fiber PA by ultrasound. In the study, the transducer was kept perpendicular to the fiber bundles and the anterior region of the supraspinatous muscle (SS) was imaged. Coronal panoramic images were used to scan fiber bundles within the middle part of the anterior region of SS. PA was measured between the fiber bundle and its attachment to the intramuscular tendon.

PA measurement of the SS by MRI in 313 subjects, was done by Simon *et al.* (2011) in axial plane using a picture archiving and communication system (PACS). Cole *et al*. (1996) studied on 4 cadavers to determine the efficacy of MRI in quantifying physiologic changes of SS after chronic tear. SS was dissected and MRI was performed in axial oblique view. Central tendon was identified and the PA of anterior and posterior region were measured. This study showed increased PA in torn tendons.

The SS is one of the four rotator cuff muscles of the shoulder and plays an important role in dynamic stabilization of the humeral head within the glenoid fossa. Among the rotator cuff muscles, SS is the most frequently involved in impingement syndrome and tendinopathy (Soo *et al.*, 2014). Therefore in this study, the PA was performed only on the SS.

Zanetti *et al. (*1993) and Ito *et al*. (1999) assesses CSA of the rotator muscles by using parasagittal MRI images. Therefore, MRI protocol for CSA measurement was based on these studies.

Strengthening the rotator cuff muscles is important due to high prevalence of shoulder injury among elite weightlifters. In traditional weightlifting training, the muscular power development is only specific at the initial segment of range of motion due to the nature of the isotonic contraction. However, isokinetic training is capable of applying maximal resistance throughout the total range of motion. Therefore this type of training is superior to traditional weightlifting training in terms of improving power output (Izzuna *et al.*, 2009).

Therefore, this study aims to evaluate the effects of FIT on muscle hypertrophy among state-level weightlifters. Eight weeks of FIT program was tailored to the weightlifters' needs. The muscle adaptations to the training program was compared to a control group which consists of weightlifters with the same level of skill. The muscle adaptations were analyzed to provide further insights for the betterment of our weightlifting team as part of esteemed sport in Malaysia.

CHAPTER 2 : OBJECTIVES OF THE STUDY

2.1 General objective:

To evaluate the size of rotator cuff muscles and muscle fiber angle of supraspinatous muscle in two different type of exercises which are fast isokinetic training and traditional isotonic training in state-level weightlifters.

2.2 Specific objectives:

1. To compare the cross sectional area of rotator cuff muscles between pre-training and post-training in subject with fast isokinetic training and traditional isotonic training in state-level weightlifters.

2. To compare difference of cross sectional area of rotator cuff muscles changes in pre-training and post-training subject between fast isokinetic training and traditional isotonic training in state-level weightlifters.

3. To compare the pennation angle of supraspinatous muscle between pre-training and post-training in subject with fast isokinetic training and traditional isotonic training in state-level weightlifters.

4. To compare difference of pennation angle of of supraspinatous muscle changes pre-training and post-training subject between fast isokinetic training and traditional isotonic training in state-level weightlifters.

CHAPTER 3 : MANUSCRIPT

3.1. TITLE: COMPARISON OF MORPHOLOGIC CHANGES OF ROTATOR CUFF MUSCLES FOLLOWING FAST ISOKINETIC TRAINING AND TRADITIONAL ISOTONIC TRAINING IN JUNIOR STATE-LEVEL WEIGHTLIFTERS

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3.2 ABSTRACT

Objective: To evaluate the size of rotator cuff muscles and muscle fiber angle of supraspinatous muscle in two different types of exercise which are fast isokinetic training and traditional isotonic training in state-level weightlifters.

Methodology: Subjects (n=16) were recruited through Majlis Sukan Negeri Kelantan. They were gender- and weight- matched and randomly assigned into traditional isotonic training group (TOT) and fast isokinetic training (FIT) group. Both groups went through 24 sessions of training programme three times per week for 8 weeks. MRI was done before the commencement of the training and after the training. MRI of rotator cuff muscles were performed and measurement of CSA and PA were done. **Results:** CSAs of the four rotator-cuff muscles increased after the intervention programme with significant improvements ($p<0.05$) found in CSA of supraspinatous muscle (SS) and infraspinatous with teres minor muscles (ISTM), but not in subscapularis muscle (SC). Significant increment in CSAs were found in all rotator-cuff muscles of subjects who underwent FIT but for subjects who underwent TOT, significant increment in CSA was only found in SS, but not that of SC and ISTM. Pennation angle (PA) of the SS significantly increased after the intervention programme. Significant increment in PA was found in all rotator-cuff muscles of subjects who underwent either FIT or TOT. **Conclusions:** Fast isokinetic training show significant increment of CSAs and PA of the rotator cuff muscles.

Keywords: *Isokinetic training, rotator cuff muscle, cross sectional area, pennation angle*

3.3 INTRODUCTION

Many of muscular injuries observed among the athletes were attributed to inadequate muscle strength. Along with the development of intervention, isokinetic exercise was introduced. Fast isokinetic training (FIT) allows maximum muscle contraction throughout the full range of joint movement (Izzuna *et al.,* 2009). Isokinetic exercise machine provides constant limb movement against resistance while the speed of limb motion and subsequent revolution per minute stay the same. Since the resistance and speed of the exercise are controlled, straining of the muscles is highly unlikely and therefore reduce the likelihood of injury. Furthermore, this type of exercise can help to improve muscular strength due to functional and structural adaptations in muscle tissue (Izzuna *et al.,* 2009). Whilst in isotonic exercise, tension remains unchanged and the muscle's length changes. Isokinetic contractions differ from that of isotonic in that in the former, the exercise speed remains constant.

Weightlifting is highly associated with weight related injuries of the shoulder joint. Typical isotonic weight training that emphasizes on large upper extremity muscles such as the deltoid, neglects the necessary training for smaller joint-stabiliser muscles such as the rotator cuff group (Barlow *et al.*, 2002; Gross *et al.*, 1993). Therefore, it is important to have a balanced strength ratio as well as the overall strength of the shoulder complex to avoid an injury. Isokinetic training can be used to restore the imbalances of the rotator cuff muscles group. Rotator cuff muscles are important to stabilise the shoulder joint during lifting. Malliou and colleagues (2004), noted that isokinetic is the most effective type of training in changing the ratio of the rotator cuff muscles compared to multi joint dynamic resistance training and dumbbell isotonic training which further reduce the risk of shoulder injury when performing repetitive lifts.

Two components in the isokinetic exercise which are concentric training (muscles shorten during contraction) and eccentric training (muscles lengthen during contraction) that can be performed separately or simultaneously. When maintained over a sufficient period, this exercise may promote functional and structural adaptations in muscle tissue (Izzuna *et al.*, 2009). However, concentric training shows better outcome as compared to eccentric training (Elizabeth *et al.*, 1996, Farthing *et al.*, 2003) because it produces greater muscle hypertrophy than concentric training. Training with a combination of concentric and eccentric training also produce greater muscle hypertrophy (Elizabeth *et al.*, 1996).

Muscular strength is higher in the trained muscle as compared to the untrained muscle after undergoing isokinetic resistance training. A study by Nickols *et al*. (2007) showed that the muscular strength of the trained leg was significantly higher than in the untrained leg of young adult women after 5 months of isokinetic training with 3 times of training per week. Guilhem *et al*. (2010) showed beyond 6 to 8 weeks of eccentric training with 3 times of training per week, the improvement in muscle capacities is observed together with an increase in muscle mass.

Muscle hypertrophy is one of the major adaptive processes induced by isokinetic training which resulted in increased force production capacities. After 6 hours of exercise there is progressive activation of genes responsible for cellular growth and development which are involved in cellular hypertrophy processes (Guilhem *et al*., 2010). A process associated with muscle hypertrophy is increased in the pennation angle (PA) of muscle fascicles. The increase in the PA leads to an increase in quantity of parallel contractile elements which in turn leads to a larger physiological cross sectional area (CSA), thus resulting in higher force production capacities (Soo *et al.,* 2014, Kawakami *et al.,* 1993). Using ultrasound measurement, Kawakami *et al.* (1993) reported a significant increase in fiber PA from 16.5 to 21.3 degree in the triceps brachii muscle following 16 weeks of resistance training. Significant increment were observed for CSA and volume of the quadriceps muscle and also muscle fiber area after 14 weeks of heavy-resistance training (Per Aagaard *et al*., 2001).

Measurement of muscle morphology can be obtained by using MRI, CT scan or by ultrasound imaging techniques. MRI is regarded as the premier imaging modality for human skeletal muscle and muscle morphometry (Walton *et al.,* 1997).

Among the rotator cuff muscles, supraspinatus muscle (SS) is most frequently involved with impingement syndrome and tendinopathy (Soo *et al.,* 2014). The SS is also one of the four rotator cuff muscles of the shoulder and plays an important role in dynamic stabilization of the humeral head within the glenoid fossa. Therefore in this study, the PA was performed only on the SS.

PA is the angle measured as the angle between the fiber bundle and its attachment to the intramuscular tendon. Previously, muscle fiber PA has been obtained from dissection of cadaveric specimens measured by ultrasound (Per Aagaard *et al*., 2001). However, more adequate measuring methods based on ultrasound have been then introduced, which makes it possible to perform *in vivo* measurement of fiber PA (Soo *et al.,* 2014). Cole *et al*. (1996) measured PA of SS by using MRI in 4 cadavers. Axial oblique view was acquired, central tendon was identified and PA of the anterior and posterior regions were measured.

CSA of the rotator muscles were assessed using parasagittal MRI images by Zanetti *et al. (*1993) and Ito *et al*. (1999). Therefore the study MRI protocol for CSA measurement was based on these studies.

Isokinetic training is capable of applying maximal resistance throughout the total range of motion as compared to traditional weightlifting training. In traditional weightlifting training, the muscular power development is only specific at the initial segment of range of motion due to the nature of the isotonic contraction. Importance of strengthening the rotator cuff muscles is due to high prevalence of shoulder injury among elite weightlifters. Therefore isokinetic training is superior to traditional weightlifting training in terms of improving power output (Izzuna *et al.*, 2009).

This study is to evaluate the size of rotator cuff muscles and muscle fiber angle of supraspinatous muscle in two different type of exercises which are fast isokinetic training (FIT) and traditional isotonic training (TOT) in state-level weightlifters. This study compared the cross sectional area (CSA) of rotator cuff muscles and pennation angle (PA) of supraspinatous muscle (SS) between pre-training and post-training in both types of training and also compared the difference of the CSA and PA changes.

This study aims to evaluate the effects of FIT on muscle hypertrophy among state-level weightlifters. Eight weeks of FIT programme were tailored to the weightlifters' needs. The muscle adaptations to the training programme were compared to a control group which consists of weightlifters with the same level of skill.

3.4 METHODOLOGY

This study is a matched parallel study whereby the state-level weightlifters were matched-pair (e.g. gender and weight) into two different training groups. The FIT group is the intervention group while the TOT group is the control group. The voluntary state-level weightlifters were recruited through Kelantan State Sports Council (Majlis Sukan Negeri

Kelantan). The ethical approval was obtained from Human Research Ethics Committee of Universiti Sains Malaysia Research Ethics Committee of Universiti Sains Malaysia (JEPem USM Code USMKK/PPP/JEPeM/[260.3(210)] which complies with the Declaration of Helsinki.

Sample size was calculated by using the G power software 3.1.9.2. The effect size was set at 0.25 which is small effect size following Cohen's (1988) recommendation. A prior power analysis indicated that 20 participants were sufficient to exhibit 0.8 power of the study. However, considering a 20% of dropout, a total of 24 participants were recruited for this study.

Recruited subjects were assigned into intervention or control groups using computer generated randomization programme. A total of 24 subjects consented to participate in the study. The study subjects were assigned into two different intervention programmes i.e. fast isokinetic training (n=8; 7 males and 1 female) and traditional isotonic training (n=8; 7 males and 1 female).

All participants were provided with detail explanation regarding the methodology of this study. Upon agreement, their consent form was collected. For participants under 18 years old, assent was obtained from their guardians.

The duration of the training programme was eight weeks. Using isokinetic exercise machine (Figure 1), the FIT group had their training sessions 3 times per week for 8 weeks at the Sports Science Laboratory, Universiti Sains Malaysia. The isokinetic training was applied using an isokinetic dynamometer (Multi-joint System Biodex Pro, Shirley, NY, U.S.A). All participants completed one set of 12 reciprocal internal and external shoulder rotation, in concentric mode after the pre-test. Participants were trained in the seated position with 45 degree of shoulder abduction, seated position with 90 degree of shoulder abduction and in standing position. Progressive load (in terms of number of sets and repetitions in each set with velocity of 120°/s, 240°/s and 360°/s) of training was completed in 8 weeks. The training programme commenced following at least 3 days of recovery.

The same lifting position was applied by the TOT group. The control group used a similar dumbbell weight throughout the duration of training programme. The same body position was applied by the TOT group using a dumbbell. The dumbbell of 5kg weight was used in this training programme for all male participants while 3kg dumbbell was provided for females' participants. The angular velocity was not fixed in TOT group.

MRI measurement of the rotator cuff muscle was performed at pre-training and post-training using a MR scanner (Philips 3 Tesla Achieva MR scanner, Best, The Netherlands). The shoulder was placed in shoulder coil with arm placed at the side of the body in neutral position with thumb pointing upward. A standard shoulder coil (SENSE_Shoulder 8) was used. MRI sequence for CSA and PA measurement was Sagittal Oblique T1 weighted image (repetition time (TR)/echo time (TE):869/20 mseconds) parallel to glenohumeral joint space. Twenty slices were acquired with slice thickness of 3mm and interslice gap of 0.3mm. This sequence covered the rotator cuff from humeral tuberosities to the middle third of scapula. Other measurements were: image matrix: 284 x 210; and imaging time: 06:10 minutes. Measurement for CSA and PA were acquired using image analysis workstation (Philips Extended MR WorkSpace 2.6.3.5, Best, The Netherlands) .

Each CSA of the rotator cuff muscles was measured at the position composed of a Y-shaped structure where the coracoid process and scapula spine met (Y-view) and at scapular notch (Tae *et al.*, 2012). CSA was evaluated with oblique sagittal images in the 25 mm medial plane parallel to the glenoid fossa (Figure 2) (Ito *et al*., 1999). Areas of each rotator cuff muscles were calculated (Figure 3). Since the border between the infraspinatous and teres minor muscles (ISTM) cannot be measured separately, these two measurements were combined (Zanetti et al., 1993).

For PA measurement, the center of humeral head was used as bony landmark. Central tendon and anterior fiber of SS were identified. Measurements of PA were taken from a specific region of musculature taken from 4-6 cm medially from the center point of the proximal humerus along the midpoint of the long axis of the SS (Figure 4). SS contains mostly muscle fibers and central tendon at this distance (Simon *et al.,* 2011). Muscle fibers tracking were acquired using image analysis workstation and PA was measured. A single reading of muscle PA was taken from the anterior portion of the SS, according to fiber insertion on the central tendon (Figure 5).

One week after the completion of eight week training MRI was repeated and measurements were documented (Figure 6 and 7). One week post training was chosen in order to give time for the training-induced inflammation of the muscles to subside (Whitehead *et al.,* 1998).

Quantitative data were analyzed using Microsoft® Office Excel and Statistical Product and Service Solutions (SPSS) for Windows, SPSS Inc.© (version 18, SPSS Inc., Chicago, IL,USA). Continuous variables were expressed as means ± S.Ds or median (interquartile range, IQR) and categorical variables as percentages. The student’s and paired-sample t-tests were performed if normality was demonstrated by histogram. Otherwise, non-parametric tests (Mann-Whitney U or Wilcoxon signed rank tests) were used. Pearson chi-square test and Fisher’s exact test were used to compare the categorical variables. All statistical tests were considered significant when the two-sided p value was < 0.05.

3.5 RESULTS

Demographic Data

A total of 24 subjects consented to participate in the present study, but only 16 subjects completed the intervention programmes, which gave a dropout rate of about 24%. The study subjects were assigned into two different intervention programmes i.e. fast isokinetic training (n=8) and traditional isotonic training (n=8). Demographic data of the participants who completed the study programme is shown in Table 1. There were no significant difference ($p>0.5$) in the gender distribution, mean age, mean height, mean weight, and mean BMI between the two different intervention groups

Changes in CSA of rotator cuff muscles after intervention programmes

Table 2 shows the overall changes in the rotator cuff muscles after the intervention programme. CSAs of the four rotator cuff muscles increased after the intervention programme, from 579.52 ± 130.72 to 640.44 ± 148.04mm^2 for SS, from 1766.64 ± 429.29 to 1855.81 ± 398.69mm^2 for SC and from 1230.74 ± 208.55 to 1317.61 ± 218.08mm^2 for ISTM. Significant improvements ($p<0.05$) were found in CSA of SS and ISTM, but not that of SC. Changes in the rotator cuff muscles according to two different trainings are shown in Table 3. Significant increment in CSAs were found in all rotator cuff muscles of subjects underwent FIT. For subjects who underwent TOT, significant increment in CSA was only found in SS, but not that of SC and ISTM. There were no significant differences in mean CSA changes of the rotator cuff muscles between subjects underwent the two different training programmes (Table 4).

To compare PA of supraspinatous muscle of subject with FIT and TOT in state-level weightlifters between pre-training and after completion of training.

PA of the SS of corresponding subjects were measured by MRI before and after the two different intervention programmes. Table 5 shows the overall changes in the SS after an intervention program. PA of the SS significantly increased after the intervention programme, from 19.78 ± 6.57 to 24.46 ± 5.87 degree. Changes in the SS by two different trainings are shown in Table 6. Significant increment in PA was found in SS of subjects who underwent either FIT or TOT. There were no significant difference in mean PA changes of SS between subjects underwent either FIT or TOT (Table 7).

3.6 DISCUSSION

Following eight weeks of FIT for rotator cuff muscles, significant differences in the muscle morphologic changes were found. Similar findings were reported by Nickols *et al*. (2007), whereby the muscular strength of the trained leg was significantly higher than in the untrained leg of young adult women after 5 months of isokinetic training. Guilhem *et al*. (2010), reported similar improvement in muscle mass as it was observed together with increase in muscle capacities after 6 to 8 weeks of eccentric training.

The mode of contraction with FIT had significant impact on CSA of all rotator cuff muscles. For subjects who underwent TOT, significant increment in CSA was only found in SS, but not in SC and ISTM. This result was theoretically due to the main function of SS is abduction of the shoulder joint and the training protocol were performed in shoulder abduction position for each rotation (internal and external rotation). Therefore the increment of CSA seen was significantly only in SS. While the main function of SC is internal rotation and ISTM is external rotation of the shoulder joint. The significant increment of CSA was observed in all rotator cuff muscles in subjects underwent FIT because of progressive loads were applied in each rotation, therefore, similar amount of load was given to each muscles.

PA of the SS significantly increased in subjects who underwent either FIT or TOT. Similar findings were reported by Kawakami *et al. (*1993) who showed a significant increase in fiber PA from 16.5 to 21.3 degree in the triceps brachii muscle following 16 weeks of resistance training which was performed 3 times per week.

Muscle thickness is a common measurement used to indicate muscle hypertrophy after training. Hypertrophy is associated with an increase in PA, in pennated muscles (Soo *et al.*,2014, Kawakami *et al.*, 1993). The increase in the PA leads to an increase in quantity of parallel contractile elements which in turn leads to a larger physiological CSA, thus resulting in higher force production capacities.

Improvement in muscle strength is known to be the result of muscle hypertrophy. Theoretically, FIT should result in greater force generation and proportionately greater improvements in strength than TOT alone. Our study findings do directly support this hypothesis as FIT is the most effective for increasing muscle hypertrophy of the rotator cuff muscles. Therefore, fast isokinetic training programme has a potential to be proposed as an additional mode of training among the experienced weightlifters to improve their performance.

MRI protocol for CSA measurement of the rotator cuff muscles by using parasagittal images are based on previous study by Zanetti *et al. (*1993), and Ito *et al*. (1999). PA was acquired using parasagittal view to obtain fascicle data and PA measurement obtained in axial view. PA measurement of this study are based on combination of methods from previous studies. Simon *et al.* (2011) measured PA in axial view by direct visualization of the muscle fiber. However in this study muscle fiber track was acquired by MRI analysis workstation due to visualization of the muscle fiber was not optimum. Different methods of PA measurement can be observed in previous studies which are measurement by ultrasound in vivo (Soo *et al.*, 2014), MRI in axial view image in cadaveric (Cole *et al*., 1996) and in vivo (Simon *et al.*, 2011) and by diffusion tensor MRI (Dongwoon *et al.,* 2014).

3.7 **CONCLUSION**

The findings of this study showed following fast isokinetic training there was significant increment in CSA and PA of the rotator cuff muscles.

3.8 ACKNOWLEDGEMENT

The completion of this undertaking could not have been possible without the participation and assistance of so many people whose names may not all be enumerated. Their contributions are sincerely appreciated and gratefully acknowledged.

3.9 REFERENCES

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